C designating raw data and D designating deconvolved data. In comparing frequency-domain to time-domain deconvolution of ultrasound data, there is considerably more distortion with higher noise levels associated with frequency-domain solutions. The biological results also show a dramatic improvement in resolution and noise reduction confirming the validity of the approach and the high performance that can be achieved. It also illustrates the theory of the PSF as completely characterizing the system's blurring and the stationary statistics associated with it.

One issue that warrants further discussion is the negative intensity values that result using linear filtering methods. The filtered images display negative values on the order of 12–20% of peak intensity values in the image. This occurs at the high-to-low intensity transitions. As discussed hereinbefore, it can be attributed to Gibbs phenomenon. The real issue is whether or not this has deleterious effects when there are strong features next to weakly fluorescing features. It should be pointed out, however, that there is no evidence of ripples, just a single negative excursion when transitioning from high to low intensity. FIGS. **10**A and B show a filtered x-y plane of cell mitochondria where all resulting negative values are set to zero (FIG. **10**A—cell_ftr.024) and where the most negative value is set to zero intensity, or stretched over the full range of intensities (FIG. **10**B—cell_str.024), whereby the negative ripples are not a significant concern.

The method of the present invention is well suited for deconvolving optical microscope images and for medical imaging modalities such as radiography, MRI and ultrasound.

Important features of the method of the present invention for filtering three-dimensional data sets includes the use of an adaptive structure to solve for the filter and the use of a one-dimensional formulation for solving a three-dimensional filter. The method of the present invention significantly simplifies the solution of an inverse filter in multi-dimensional problems. The prior art filtering methods involve frequency-domain transformations and/or non-linear processes that either impair ultimate performance, slow the process or both.

There are many advantages of the present filtering method over the prior art filtering methods. The three-dimensional filter is solved using an adaptive structure for a one-dimensional adaptive LMS structure. The adaptive LMS solution has shown results that are superior to other solutions in one-dimension. The use of a synthesized "desired" data set as the a priori desired result from the filter. Prior deconvolution systems either do not use an a priori desired data set or it is not available as a measure of filter performance. A direct comparison to the a priori desired output avoids the formation of artifacts associated with frequency-domain solutions. The solution is entirely solved in the spatial-domain. The frequency-domain is typically used is due to the fact that convolution in the spatial-domain is equivalent to multiplication in the frequency-domain. A transfer-function (TF) is represented as a function of frequency with the inverse TF being simply 1/TF. This approach does not completely solve the problem since, as stated hereinbefore, the solution does not exist across the entire frequency spectrum (i.e., the inverse of zero's in the TF become unstable). The solutions have been made to work by making modifications to address the instabilities. Although the frequency-domain solution can be made to work, the quality of the results are impaired due to artifacts of the transformation process to and from the frequency domain. Some of the known artifacts due to frequency-domain transformations are: assumed periodicity in the data, aliasing, digitization error and Gibb's phenomenon. The adaptive LMS deconvolution filter results in low noise by adapting to suppress unwanted responses. Prior methods typically perform an adequate deconvolution but are adversely affected by noise. The present invention eliminates the need for smoothing or low-pass filtering and consequently can achieve the highest resolution possible. The filter implementation of the present invention has an automated means for determining μ (the convergence coefficient) that assures stability and accelerates convergence with better performance. The known relationship between the convergence criteria and the overall signal power is used to initialize μ such that stability is assured. Then μ is reduced non-linearly as a function of the iteration number. This process of reducing μ has two benefits: (1) accelerated convergence with (2) better performance. Further, it is believed that prior art systems do not use an algorithm for reducing the convergence coefficient. Instead, a stable value for its convergence coefficient is found and held constant during the iterative process. With the present invention the filter kernel size can be varied in x, y and z. Prior art methods typically use fixed-sized kernels. The ability to size the filter for optimum performance for both filter quality and time required for calculating the solution is an advantage over existing methods. Further, with the present invention once the filter is solved for a given setup, the filter can be applied to any image acquired with the same parameters. This allows the filter to be re-used thereby avoiding the large block of time required for generating a solution. The solution can be applied to any three-dimensional image data set that was collected with the same parameters such as voxel size in x, y and z and using the same glass cover slips. This is an advantage over existing methods since the solution can be applied quickly (a few minutes—the amount of time needed to convolve the filter with the data set).

While preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustrations and not limitations.

What is claimed is:

1. A method of deconvolution filtering image data from an imaging system having a point spread function, the method comprising:

obtaining image data generated by the imaging system, the image data representing convolution of the point spread function of the imaging system and an image of a source object that is known a priori;

in the spatial-domain, filtering with an FIR filter said image data to provide filtered image data, said FIR filter having a plurality of coefficients;

in the spatial-domain, comparing a synthesized representation of said source object and said filtered image data to generate an error function;

adaptively adjusting said coefficients to determine a minimum of the error function;

ending said adjusting of said coefficients to provide fixed coefficients;

using said fixed coefficients to filter subsequent image data in a non-adaptive manner;

wherein said FIR filter deconvolves said image data;

said image data comprises three-dimensional image data and said FIR filter includes coefficients for each of said three dimensions; and